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PHOTOVOLTAIC (PV) SOLARSYSTEM SIZING FOR OFF GRID SOLAR HOME SYSTEMS

SEBASTIAN WAITA & BERNARD ADUDA

Department of Physics, University of Nairobi, Nairobi, Kenya

ABSTRACT

The sun releases tremendous amount of energy, which if harnessed would provide all energy needs of mankind. One of the strategies to trap this immense energy is the use of solar modules/panels. However, these solar modules need to be properly sized and installed to be able to function and generate electricity optimally. The successful installation of an off grid Photovoltaic (PV) solar system is a process that begins with a site visit to the area of installation, the determination of the client's energy needs, installation of the solar PV system, commissioning of the installed solar system and ends with user training. Every step is critical for it determines the final performance of the solar system and hence the delicate balance between a satisfied or unsatisfied client. However, the system sizing step tends to attract more attention for it determines the system size and the matching of the balance of system components and so if this is not properly done, then the entire system may not perform as intended. Most documented sizing methods tend to be too complicated and require significant computer knowledge in simulation, modeling and even programming. For practical purposes, many designers and PV installers, especially in developing countries have basic education may not be well equipped for these complicated sizing methods. Furthermore, very few have been professionally trained in PV solar system Sizing and although there are commercially available sizing software's, they are too expensive for majority of the people and even if available, they are too complicated for them.In actual sizing therefore, most untrained PV technicians use mere estimates that may not be appropriate for the outcome, more often than not is disappointing. We present a simple sizing method that can easily be learned andapplied in a simple calculation, for example in a simple excels sheet formulas for easier sizing of PV systems. The method is recommended for adoption in developing countries for faster dissemination of professional PV services in system sizing.

KEYWORDS: Installation, Method, Off-Grid, Photovoltaic (PV), Sizing

INTRODUCTION

Energy is very key to any country and is one of the key determinants of development in any country. Energy shortage definitely undermines efforts for social and economic development. Africa and more specifically, sub-Saharan Africa has been considered as lagging behind in development compared to the rest of the world and one of the components of development to consider is the availability as well as affordability of energy. The population explosion in Africa is not well matched with its rising energy demand. For example, between 2000 and 2012, the energy demand for sub-Saharan Africa grew by 45 % (which is only 4 % of the world's total energy demand) although the region accommodates 13 % of the world population [1]. Yet, this energy demand can be significantly reduced by exploiting the continents vast renewable energy resource base.

Kenya is one of the countries in the sub-Saharan Africa which has high potential for renewable energy, especially

solar power. The government of Kenya has realized this and has taken measures to tap into this in exhaustible resource and has therefore put in place policies to guide retailing and importation of solar system components as well as installation and maintenance of PV solar systems. Furthermore, the government has also zero rated solar components as an incentive for investment into the solar power generation. As a results there has been an up heave of activities in the renewable energy sector in Kenya, especially on photovoltaic solar systems. The creation of the Energy Regulation Commission (ERC) to regulate the energy sector only created a 'solar energy rush' to meet the ERC requirements for licencing to deal with solar photovoltaic systems [2]. Due to the high number of people in need of specialized training, a number of institutions including the Department of Physics, University of Nairobi, have taken up the challenge and begun training of solar technicians mostly at the technician 2(T2) level. As a result, within two years, the Department trained over 200 technicians and as of now, over 300 technicians have been trained [3].

A professionally installed solar system has to go through a number of steps: site visit, system sizing and design, system installation, testing and commissioning and user training. The designing, sizing and the installation are very critical steps. When a system is wrongly designed, sized and installed, it will not perform optimally. A number of sizing methods exist and have been tried and they work. However, most of them are complicated and require great understanding of computer modeling, simulation and even programming [4-13]. In many developing countries, the sales person is both the installer and also the PV system sizer, though in most cases, with very limited knowledge in the area of PV sizing. The tendency is therefore to use mere unjustified estimates which more often than not do not meet the clients need. A simple straight forward method is needed for the individual with basic education and who wants to do professional PV sizing, especially in the rural developing world.

In this work, we present a simple sizing method which can easily be adopted by the PV professional with basic education and limited computer knowledge and skill. We designate the method as the Charging Current Method (CCM).

SIZING COMPUTATION

System Sizing Steps

Step 1: Visit the Site of Installation

A site visit is always necessary before any work on system design and sizing begins. The site visit helps the installer to: have a real assessment of the solar resource in the area, create an impression of how the system will be installed, assess any impediments to the system installation like nearby trees, roof thatching, terrain and assess the risk and hazards involved in the work.

Step 2: Determine the Solar Resource in Peak Sun Hours (PSH)

The amount of irradiance in the area determines how much energy the modules can generate. The solar resource available in the area is therefore very necessary. This can be obtained from either the nearest meteorological station or do actual site measurements if we have the right equipment (but this may take some time) or even get it from reliable internet resource maps. In sizing calculation, we use PSH(how many hours we would have the same energy if the irradiance was the standard 1000 W/m^2 (1KW/m^2). The irradiance per day then needs to be divided by the standard value solar irradiance on the earth's surface, 1000 W/m^2 or 1 Kw/m^2 to get PSH.

Step 3: Compute the Daily Energy Demand (DED)

Next we need to determine the daily energy demand required by the user. We do this by talking to the user about their needs and future plans so we can factorthat in the design and sizing. The items can be tabulated as shown below in Table 1.

Table 1: Details of the Load Requirements

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
Room	No of Lights/Appliances	System Voltage (V)	Appliance Power Rating (W)	Daily usage (Hrs)	Total Power (W)	Daily energy Demand (Whrs)

In Column 1, the place/room in the house where the light or appliance will be located is entered. Column 2 is for the number of appliances or lights per room that will be powered. In column 3 indicate the system voltage while the power rating of each appliance is entered in column 4. The estimated number of hours each appliance will be in use per day is in column 5. The total power for each appliance is obtained by multiplying column 2 and column 4 and the value entered in column 6. Lastly the amount of energy needed for each appliance is obtained by multiplying the number in column 5 by that in column 6 and the product entered in column 7.

The total power needed by all the appliances is the sum of the values in column 6 (We shall need this value for the inverter sizing). The content of column 7 is also summed up giving the total Daily energy demand (DED) for the user in Watt-hours (Whrs). Since system components are never ideal, we allow a margin of about 25 % loss. Therefore we add 25 % of the total in column 7to get the final DEDin Whrs.

Step 4: Fourthly, We Determine the Number of Solar Modules Needed. Step 4 Has Six Steps:

4.1. Determine the system voltage, V_{syst}. We can estimate this from the DED. Practice has established that for an insolation of 5.6 Kw/M^2, for DED less than 1Kwhrs or there abouts(or a sum of module wattage of about maximum 150 W), a 12 V system is required, 1-3Kwhrsor there abouts(or a sum of module wattage of about 200-800 W), a 24 V and 3-4 Kwhrsor there abouts(or a sum of module wattage of about 900-1200 W), a 48 Vetc. This can be used as a guide but care should be exercised as other factors like cable sizing may make it necessary to adjust the system voltage

4.2. The next step is to estimate the charging current needed from the modules. We do this by diving the final DED in Whrs with the system voltage, giving us the DED in Ampere hours (Ahrs). The DED in Ahrs is then divided by the PSH to give the charging current required from the modules to meet the DED.

4.3. We now have enough information to go to the market and choose thea suitable combination of module sizes that will give roughly the charging current form the maximum current rating, I_{max}. The module performance in the field will be less than the indicatedI_{max}. We assume a loss of about 20 %, so our I_{max} will be (I_{max}) x0.8 to get the real field value, I_{real}.

4.4. Divide the charging current by the real maximum current, I_{real} to get the number of module parallel strings, N_p,you will need in the system. Please note this is not the number of modules but number of parallel strings you will connect to give the charging current.

4.5. We now determine the number of series modules, N_s, connected for each parallel string. This is achieved by dividing the system voltage by 80 % of the maximum power voltage (V_{max}) i.e. system voltage/(0.8 x V_{max}).

4.6. Lastly, we calculate the total number of modules, $N_t$we need. Multiply the number of parallel strings, N_p by the number of series connected modules per string, N_s. You can also recheck your system voltagesince a 36 cell module is intended for 12 V.

Step 5: The Fifth Stepis the Determination of the Battery Bank Capacity Needed.

This step has five components:

5.1. The battery bank capacity (Ahrs) needed in a day is now determined, i.e. the total energy we need from the batteries in a day. This is not the number of batteries. To calculate the battery bank capacity, we multiply the DED in Ahrs by the days of autonomy (the number of days we wish to have energy supply from the batteries when there is no sunshine-usually about 3) and divide this product by the depth of discharge (DOD), (how much energy you can safely use from the battery to avoid excess draining) as a decimal. Some designers prefer a DOD of 50 % (0.5) and others 20 % (0.2). We use the50 %. Take note that the lower the percentage of DOD, the larger will be the battery bank.

5.2. Choose the battery size (rating) you will use from what is available in the market.

5.3. Next determine the number of battery parallel strings, N_{bp}. Divide the battery bank capacity (Ahrs) with the rating of battery chosen (Ahrs)

5.4. Determine the number of batteries connected in series, N_{bs}, in each string of batteries. Divide the system voltage by the voltage of one single chosen battery.

5.5. Now get the total number of batteries, N_{bt} needed by multiplying the number of parallel strings by the number of series connected batteries in each parallel string.

Step 6 Sizing the Charge Controller

The charge controller size is determined by the maximum current that can flow through it. We use the total short circuit current (I_{sc}) that all the modules can generate. This is computed by multiplying the I_{sc} of a single module by the number of module parallel strings. We then allow a margin of 25 % so the total current through the charge controller becomes the total current from all the modules multiplied by 1.25. The charge controller with a current rating higher than this calculated current is chosen. It is important that the charge controller is of the same voltage as the system voltage. If the user thinks of future expansion of the system by way of adding new appliances or another room, consider factoring this in the controller sizing.

Step 7 Sizing the Inverter

The total power needed on daily basis provides a basis for estimating the inverter size. So we get the sum of column 6 in table 1, above and then factor in inverter conversion losses of 5 %. So we add 0.05 x the sum of column 6, to the sum of in column 6 to get the minimum power rating of the inverter. Chose the inverter in the market that has a rating

closest but higher than the value obtained. If the PV system is purely direct current (DC), then an inverter is not needed.

Step 8 Cable Sizing

Cable sizing must be done carefully to minimize voltage losses due to resistance. Cable size is usually given in terms of the cross sectional area of the cable in mm^2 or wire gauge-America system. The thicker the cable, the lower the resistance; but he higher the cost. Generally, the recommended maximum voltagedrop is about 5 % of the system voltage and is used a guide for cable sizing. The cable cross sectional area is related to the voltage drop, length and current flowing through the cable by:$A = \frac{2\rho LI}{V_d}$ where A is the conductor cross section area (mm^2), ρ is the resistivity of the conductor material in Ωmm^2/m (for copper it is 0.0183), L is the conductor length one way (no return) (m), I is the current flowing (A) and V_d is the voltage drop along the conductor (0.05 x system voltage). This calculation can also be used to calculate the maximum cable length to give a voltage drop within the limit of 5 % for a particular cable size. If the cable size obtained by calculation is not in the market, then chose the next cable of larger size.

Example

The calculation is applied to a client whose DED is 904 Whrs and the total power for all appliances is 168 W. The insolation at the place is 5.5 Kw/m^2.

RESULTS AND DISCUSSIONS

The total charging current is 16.95 A and this requires four strings of 80 W if each module has a maximum current of about 4.4 A (parallel connection). This can be considered as a 24 V system so each string has two modules in series. The total number of modules is therefore eight. The total battery bank capacity taking into consideration three days of autonomy is about 1412 Ahrs. If 200Ahrs batteries are available in the market, then we need about seven of them. It is advisable to have an even number of batteries so we can have six. The batteries must now be connected in such a way that the total battery voltage is equal to the system voltage which is 24 V. Thus, there will be three strings of two batteries in each string. The maximum current through the charge controller is about twenty six Amperes, so a 30 A/ 24 V charge controller is good enough. Since the total watts in the system are 168, an inverter rating of 300 VA would do. The wires from the inverter to the loads can 1.5 mm2 but that from modules to the charge controller and between the charge controller and inverter or battery to inverter depending on the system connection should be large enough for a current the size of the charging current to flow through without overloading the cable.

CONCLUSIONS

A simple method of PV solar system sizing has been presented for sizing the main system components. Usually in most PV solar system sizing, these components pose the greatest challenge. The method is straight forward and easier to learn and use than other many available methods. When applied it will provide a good estimate of the solar system size for an off grid solar home system.

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